

Title: "Interactive Classification Technology"

Type of Report: Performance Report, submitted October 19, 1999

Principal Investigator: Cary deBessonet *deB*

Period Covered: 1/1/99 - 10/14/ 99

Institution: Southern University Law Center
P.O. Box 9294
Baton Rouge, LA 70813

Grant No: NAG 2-1273

1.0 Goals, Accomplishments and Findings

The investigators are upgrading a knowledge representation language called SL (Symbolic Language) and an automated reasoning system called SMS (Symbolic Manipulation System) to enable the technologies to be used in automated reasoning and interactive classification systems. The overall goals of the project are:

- a) the enhancement of the representation language SL to accommodate multiple perspectives and a wider range of meaning;
- b) the development of a sufficient set of operators to enable the interpreter of SL to handle representations of basic cognitive acts; and
- c) the development of a default inference scheme to operate over SL notation as it is encoded.

As to particular goals, the first-year work plan focused on inferencing and representation issues, including:

- 1) the development of higher level cognitive/ classification functions and conceptual models for use in inferencing and decision making;
- 2) the specification of a more detailed scheme of defaults and the enrichment of SL notation to accommodate the scheme; and
- 3) the adoption of additional perspectives for inferencing.

The technology at this stage is being developed to process factual information (descriptions) with a view towards using it generally in rule-based systems, particularly in those designed to function as "cogitating" mechanisms, such as robots. Most of the research during the reporting period focused on goals (1) and (2), both of which were achieved to the satisfaction of the investigator. The encoding and processing of perspectives were treated as part of the specification of syntax and rules of inference; hence, goal (3) was reached as part of the achievement of the first two goals. In SMS, perspectives include both individual and global points of view. The system interpreter would maintain a global point of view, for example. The functions and models referred to in goal (1), as well as the additional perspectives of goal (3), depend on the availability of a notation that is capable of accommodating information needed to build models and to represent perspectives. Accordingly, much of the research effort was spent on the enhancement of SL (Symbolic Language), the representation language being used in the project. The syntax rules of SL, for instance, must strike an appropriate balance between providing information by means of explicit encoding as opposed to inclusion by default. This consideration is particularly important since SMS allows for multiple perspectives to be encoded simultaneously. Allowing the scale to dip too heavily in the direction of explicit encoding would result in the notation becoming too tedious for practical use. First-year accomplishments include:

- 1) the specification of a more flexible syntax and semantic theory for the language;
- 2) the development of a syntax checker to ease encoding tasks; and
- 3) the development of a broader range of syntactical functions for use by the interpreter of the system.

CASI

After sufficient progress was made in the improvement of SL, new features were added to SMS (Symbolic Manipulation System), which functions as an interpreter and knowledge base manager, to enable the system to handle extended SL notation. Special functions and models were developed for use in interpretation and inferencing over a variety of SL sentence types, including those that employ special modal syntax or operators. Since SL is being designed as a general representation language capable of handling a wide range of objects, including processes and events, SMS has been designed to recognize and incorporate ontological distinctions into its knowledge bases. Considerable effort was directed during the current term towards improving the inferencing and retrieval capabilities of the system. The results of that effort brought about the most important progress achieved during the first year. The goal was to design a scheme of inference and retrieval that would help the system to interact with the user in a conversational mode. Since much of what takes place within ordinary human conversation can hardly be said to be analytic or deductive in nature, the system is being designed to handle nonstandard, even tainted, inferencing.

In SMS, tainted inferencing is referred to as "penumbral inferencing" and is stipulatively defined as inferencing that is neither deductive nor probabilistic. Although penumbral inferences are nonstandard, they are quite useful and are seemingly indispensable for the successful operation of technology of this kind. SMS recognizes multiples bases of penumbrality (taintedness of inference), including those rooted in disjunction (indefinite reference), indefinite existential import, and imprecise expression.

In SMS, "reality" is conceived of as an ontologically diverse complex of objects and relations over which inferencing is defined. The idea is to describe this complexity in SL assertions and have SMS interpret the assertions in constructive mode to produce a "sentential reality". Ontological diversity is captured by employing a system of assignment by which values are assigned to objects to indicate their ontological status. Each sentential object of 'reality' is *signed*, that is, each object carries one or more values that describe its status or presence (cf. truth) within the system.

SMS recognizes persons, things, states and events as objects when they are individuated, that is, distinguished by a unique marker. Objects are classified throughout SMS using multiple bases, such as whether the object is:

- 1) divisible or indivisible;
- 2) commutable or not;
- 3) associative or not;
- 4) transportable or not.
- 5) an abstract concept or an instance of a concept;
- 6) a single entity or a group;
- 7) a present object or a penumbral object; and
- 8) a class or not.

Each of these bases is defined for particular purposes, and each affects inferencing in specified ways. The classification of an object as "divisible" or "indivisible," for example, determines whether it may be divided without affecting its ontological status (e.g. its existence in a particular realm). Disjunctive objects, such as a sequence of the form $\langle ?a \text{ or } \langle ?b \text{ or } ?c \text{ or } \dots ?n \rangle \rangle$ (where "?" flags variables) are indivisible within the realm of OW (for "Ordinary World"). Such an object cannot be divided without the results being transported to another realm. This object, although indivisible in the realm of OW, is both commutable and associative within that realm. The effects produced are obvious. Given the presence of the assertion ' $\langle \text{john or } \langle \text{mary or jim} \rangle \rangle$ is tall' in the realm of OW, the following inferences would be allowed in OW without the results being transported to another realm:

- a) the commutative inference ' $\langle \langle \text{mary or jim} \rangle \text{ or john} \rangle$ is tall'; and
- b) the associative inference ' $\langle \langle \text{john or mary} \rangle \text{ or jim} \rangle$ is tall'.

On the other hand, the inference ' $\langle \text{john} \rangle$ is tall' (which would result from division) would not be allowed and, as such, would be transported to another realm, namely, DW (for "Disjunctive World"). An assertion such as ' $\langle \text{john caused } \langle \text{mary is happy} \rangle \rangle$ ' would be neither commutable nor associative in OW.

Research for the current term convincingly confirmed suspicions that for SMS to reach its potential, it must employ a many-valued scheme of inference and must be able to map out its lines of reasoning for the user. First-year accomplishments geared towards satisfying these requirements include:

- 1) the development and integration of tractable inferencing and retrieval functions;
- 2) the design of a multifaceted SMS universe for housing divergent domains (including ontologically distinct sub-domains).
- 3) the optimization of SMS KBs;

These accomplishments required that particular issues be addressed, such as those that entail:

- 1) recognizing multiple bases for indefinite existential import;
- 2) handling defeasible assertions;
- 3) qualifying sentential components with modal operators.

2.0 Reservations

Although first-year goals were achieved, there are many areas that need further development. The is so because the representation and inferencing issues posed by the incomplete and imprecise environment of SMS are quite formidable and cannot be resolved by short-term efforts. The investigators are designing the technology so that useful components can be added incrementally.

3.0 Planned Visit to NASA Ames

The principal investigator is making plans to visit NASA Ames Research Center near the end of the year to demonstrate some of the progress that has been made in the first year and to discuss plans for the second year of research.